

NOTES AND COMMENTS ON CLASSIFICATION OF HYDROMETEORS.

The comprehensive analysis and classification of hydrometeors by Dr. Hellmann, accompanied as it is by many historical references, will prove of great value to meteorologists and, we are confident, will be accorded the commendation of the officials and observers of the Weather Bureau and American meteorologists generally. The present writer is prompted to offer a few comments suggested by some of Dr. Hellmann's statements, as indicating in some cases, possibly, the views held in the United States on the points in question, and mentioning in the case of glaze the physical principles that seem to underlie and determine the formation of this hydrometeor.

The reader will be able to identify those portions of the original text upon which comments are offered by reference to the boldfaced numerals found on the pages indicated in () at the beginning of each of the following notes.

(1, v. 44, p. 386.) Sweating is *visible* on the stone pavements under the conditions described, but it is unnecessary to assume, as seems to be implied by the text, that sweating is absent on adjacent cold soil and other cold objects. The nature of these surfaces is such that the hydrometeor is invisible, but the condensation forms on such cold surfaces as well as on the pavements, even though it be inconspicuous or invisible.

The idea that some of the moisture which contributes to deposits of dew comes originally from the soil seems to be an unimportant consideration. Even if some water rises from the soil and evaporates, it deposits only after it gets into the air, and the distinction between "sweating" and "dew," based on the consideration that in the case of dew some of the moisture comes from the soil, does not seem to be as fully justified as Hellmann suggests. Here we expressly disregard local variations in condition, in texture, and in composition of the soil with their concomitant effects on hydrometeors.

(2, v. 44, p. 386.) Closely related to "sweating" may be mentioned the pseudo-sweating that may be observed on many humid days when certain objects acquire a moist, clammy condition of their surfaces, not because they are colder than the air but because they attract an appreciable film of dampness from the heavily moisture-laden adjacent atmosphere. This deposit forms even though the temperature of the surface be above the dewpoint; it is caused by a more or less pronounced hygroscopic property possessed by the surface upon which the deposit has been formed. The ladies, especially, are distressed by the formation of this hydrometeor, which causes their hair to become limp with dampness and sadly interferes with its arrangement, particularly where artificial curling is resorted to. The hygroscopicity of the surface is often due to a filmlike coating of foreign materials acquired by handling or otherwise, and may commonly be noticed on the handrails of stairways.

(3, v. 44, p. 388.) Under these conditions especially, surface objects are likely to cool by radiation to a point of temperature even lower than the air strata, thus further facilitating the deposition of water thereon. The fog-free spots, usually at a higher elevation, are simply evidences of the strong inversion of temperature that prevails under conditions of this character. Physically, the conditions causing dew and ground fog seem to be identical, except that the drop in temperature in the latter case is carried to a greater degree, as it were; that is, not

only are surface objects cooled below the dewpoint of the air, but the lowest stratum of air is cooled throughout much below its dewpoint, resulting in a fog formation. While obviously Chistoni's distinction between moisture settling from the fog masses and that forming literally as dew, is justified, nevertheless it seems quite improbable that an observer can discriminate between the two hydrometeors.

(4, v. 44, p. 389.) Data seem to be lacking in the United States to definitely establish the truth of the author's statement that rime (*Rauhreif*) belongs largely to the lowland phenomena and *Rauheis* rather to the high mountain localities. If we clearly understand the distinction between these hydrometeors, the experience in the United States indicates that almost the reverse takes place; that is, rime occurs with frequency at mountain stations and is naturally an accompaniment of fog which occurs frequently in these localities with relatively lower temperature, whereas *Rauheis* is more frequently observed in the lowlands, as might naturally be expected, particularly because of the less frequent occurrence of fog with low temperature at low levels and the frequency of conditions of deposition of undercooled fog or water droplets solidifying to ice upon striking the supporting object. (See also an illustrated note by W. R. Blair on *Rauheis*, below p. 19.)

(5, v. 44, p. 390.) The attempt to measure the quantity of deposit of rime, as the author indicates, must be regarded as only of a very relative value. It might be interesting to devise a standard method of determining the amount of deposit of this hydrometeor on some standard type of collecting object. Such observations would be specially appropriate at a relatively few stations at which this deposit occurs with some frequency.

(6, v. 45, p. 13.) It seems important to emphasize the probable unreliability of observations which claim to report rainfall without clouds. In the fall of 1906 the writer of this note was traveling from Los Angeles, Cal., to Salt Lake City, Utah, via the San Pedro, Los Angeles & Salt Lake R. R., which runs for many miles over the bed of the extinct Pleistocene lake which Mr. G. K. Gilbert has called Lake Bonneville, now a great semi-arid alluvial plain. In the middle of the afternoon in the midst of bright sunshine a very appreciable shower of scattered rain drops fell about the train while standing at a small station not far from Modena, Utah. Many careless observers would doubtless have been prompted to say this was "rain out of a clear sky;" the careful observer, however, could easily have found, not far distant, a few but sufficient clouds to destroy the belief that the rain came from a literally cloudless sky.

(7, v. 45, p. 14.) To my mind, dry, powdery, very cold snow does not *creak* under foot or wagon wheel. This hydrometeor must necessarily accumulate on the ground in a noncoherent condition resembling dry sand or meal, and therefore yields more or less noiselessly to the foot and wheel, which sink deeply into it. Snow which *creaks* under foot and wheel is snow which has previously fallen, either relatively wet at the time or subsequently subject to some melting in place and with an appreciable water content. The boys have probably snowballed with and built fortifications of it, but the cold, clear night that follows the snowstorm has cooled the snow blanket far below the freezing point and all its parts are a continuous mass of ice and snow crystals. We awake in the morning after such a night, to hear the snow cover creaking and screaming as the wheels of the milk carts and bread wagons break up and fracture its icy structure.

There is some room for confusion between two possible phenomena in this connection. To many ears the sound made when walking or driving over a certain kind of snow is best described by the word "creak" (Ger., knarren, kreischen), or even "crackle" (Ger., knistern), while on another occasion or to another ear the sound heard may better be called a "crunching" (Ger., knirschen). Tyndall ("Glaciers of the Alps") remarked the "crackling" of the snow under his feet as he walked. * * * Most of us would say the commoner phenomenon is a "creaking" of the snow under foot or wheel in the morning hours, and a "crunching" when the snow is but slightly moist and is *packing* under foot.

It appears that there are really two distinct physical conditions or states of the snow involved in this matter of creaking and crunching. In the one case we are dealing with the action of snow in which there is molecular continuity throughout a porous aggregation of snow crystals. This condition results from the subsequent freezing of snow that has previously been in a wet and semi-melted condition, after which freezing the condition of molecular continuity of matter mentioned above is established. Mechanical force applied to this snow produces the creaking and screaming already described.

The second physical condition of the matter arises when snow falls during particularly low temperatures. In this case there is lack of molecular continuity of structure, the mass simply being an aggregation of discrete snow particles. Such snow, subjected to the mechanical forces of walking or the rolling of wagon wheels, emits the sound better described by the word crunching, and we may properly, therefore, use the word "creaking" or "screaming," which describes the fracture of molecularly continuous snow masses, and the word "crunching" to describe the more subdued sound that results from the behavior, at very low temperatures, of snow the physical structure of which is of a granular nature.

THE FORMATION OF GLAZE (GLAZED FROST, GLATTEIS).

(8, v. 45, p. 16). The analysis of the formation of glaze seems insufficient, and important physical considerations seem to have been disregarded. According to the author, glaze is formed by one or more of three methods:

(1) Undercooled rain (presumably falling on objects not already cooled below the freezing point).

(2) Ordinary rain falling on a very cold ground, vegetation, etc.

(3) Deposition from a fog. (This is of minor consequence.)

The next paragraph opens with the statement that "a heavy deposit of the glaze is produced only by the first of the three processes." The physics of the freezing of undercooled water seems to controvert the truth of this assertion, as will be indicated in what follows.

The paragraph following states that "processes (2) and (3) * * * require the ground to be frozen and in both cases the incrustation *attains but slight thickness.*"

These statements do not seem to be in accord with observations of the phenomena in the United States. Since Hellmann's cases (2) and (3) include those conditions in which the temperature of surface objects is assumed to be below freezing, we conclude by inference that the temperature of surface objects in case (1) is at least not below freezing and may be above. How can the freezing of undercooled water drops form a *heavy coat-*

ing of ice on the ground and other objects whose temperature is no lower than the freezing point, and possibly higher?

Let us briefly examine the physics of the process. Assume the most favorable case, namely, that surface air and objects are at the freezing temperature. The latent heat of fusion is 80 thermal units, and if the rain-drop is undercooled by say 8.5 degrees (C.), then when freezing sets in 1/10 of the water will suddenly solidify and the latent heat thus liberated warms the remaining 9/10 of the drop, including the ice, to the freezing point, and a state of equilibrium will then exist as regards further freezing. That is, this 1/10 of a drop that is frozen is adhering to an object that is assumed to be at 0°C. The surrounding air is also assumed to be at the same temperature and there is no influence to induce further freezing except possible cooling by radiation and evaporation, which under the conditions must be inappreciable. On the other hand, assume the surface air and objects to be slightly warmer than the freezing temperature, then the whole influence of the environment will be to *melt* the 1/10 of a drop that has frozen from the undercooled water, and the question is, how can a *heavy* coating of ice grow under such conditions? Undercooling alone is quite inadequate quantitatively to account for heavy ice coatings and the destructive accompaniments of our great "ice storms."

The freezing of undercooled raindrops may be mathematically indicated by the following equations:

Let n = number of degrees of undercooling of the drop,
 w = weight of the drop,

x = weight of portion that freezes adiabatically or by virtue of the undercooling and without exchange of extraneous heat.

λ = latent heat of fusion or about 80°.

c = specific heat of ice, 0.46.

When fusion takes place a mass of ice, x , suddenly forms and latent heat, λx , is liberated. We assume the mass x and the whole drop are as yet at the undercooled temperature t . The latent heat liberated is set free within every molecule of the drop, however, and warms it up, including the ice. The freezing and the warming automatically stop as soon as the temperature of the whole drop is brought to the freezing point. The heat liberated equals that absorbed by warming, that is, neglecting certain terms of secondary magnitude,

$$\lambda x = (w - x)n + cnx. \quad (1)$$

The first term of the second number is the heat absorbed to warm the water not frozen to 0°C. The second term is the heat absorbed in heating the ice to 0°. From (1) we get

$$x = \frac{wn}{\lambda + (1 - c)n} = \frac{wn}{80 + 0.54n}. \quad (2)$$

If n is about 8.5 degrees x will be about $w/10$. Transposing the equation we get

$$n = \frac{80x}{w - 0.54x}. \quad (3)$$

The undercooling necessary to freeze the whole drop suddenly must not be less than the value of n in (3) when $x = w$ or $n = 80/0.46 = 174$ degrees. These numerical magnitudes are only approximate because both the latent heat of fusion and the specific heat of ice are not constant for the wide ranges of temperature discussed.—C. F. Marvin.

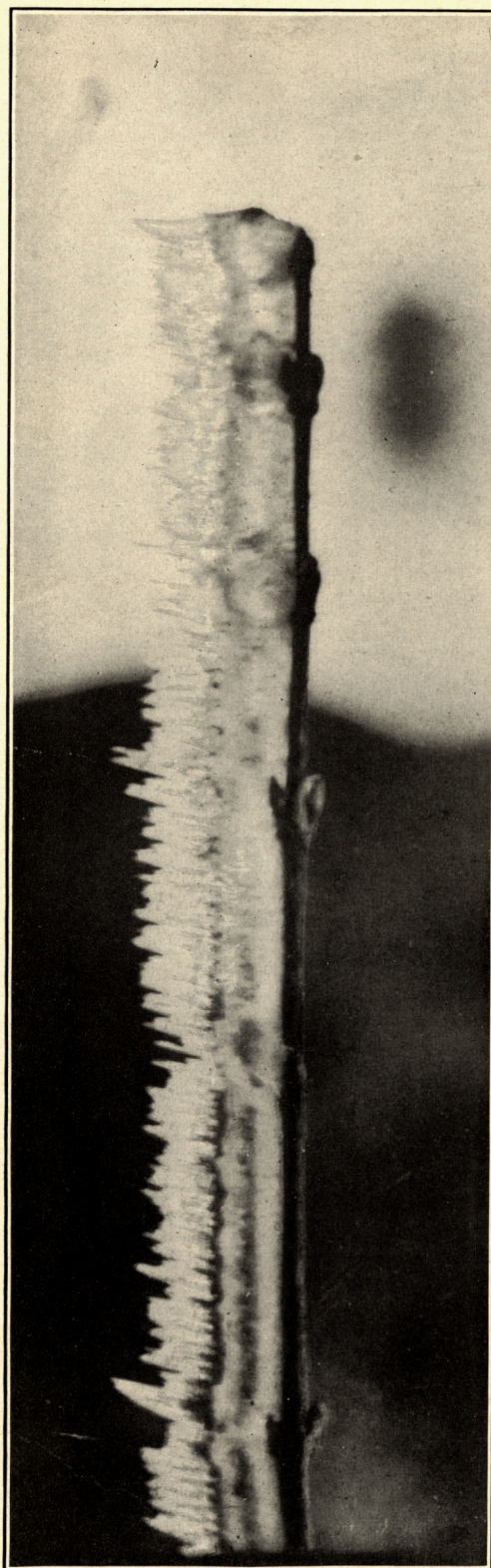


FIG. 1.—Photograph, natural size, of twig loaded with alternate deposits of rime (Rauhreif) and rauhs. Mount Weather, Va., Feb. 20, 1914.